From Dinosaur Bones to Software, Gamma Rays Protect Property

The Gamma Watermark team members are, from left to right, Ronald Lougheed, Tzu-Fang Wang, Muriel Ishikawa, Lowell Wood, Winifred Parker, and Kenton Moody.

LAW enforcement officials have long searched for a way to solve a frequently vexing problem: determining the rightful ownership of everything from paintings to dinosaur bones to computer software. The problem has worsened in the past few years as increasingly sophisticated counterfeiters have flooded markets with illicit copies of a vast range of goods, and thefts of precious items have skyrocketed.

A Livermore research team has come to the aid of law enforcement agencies with an ingenious solution that uses a combination of radioisotopes, gamma-ray spectroscopy, and computer-driven inkjet printers. During the past year, the team developed a novel technology that produces watermarks (unique identifiers) that establish indisputable links between owners and their property.

The team's Gamma Watermark process puts a unique, date-stamped tag of nearly microscopic size on or within an object and does so easily, inexpensively, and safely. The essentially invisible watermark, containing a precisely metered mixture of radioisotopes, can be sensed and read out for decades thereafter with an appropriate detector. Use of the Gamma Watermark establishes ownership irrefutably and is analogous to DNA fingerprinting.

The new technology promises to be as revolutionary a method of identification and authentication as the digital watermark has become to digitized visual and audio data. The process is applicable to a vast range of material objects, from artwork and CD-ROMs to paper items such as contracts and deeds. In contrast to other forms of watermarking (digital, paper, and embedded silicon chips), the process should enjoy far wider applicability because of its low cost, tiny size, ease of use, and safety.

Signatures with Radioisotopes

Gamma watermarking produces a unique digital signature using minuscule quantities of combinations of rare and long-lived isotopes that emit extremely low levels of gamma radiation. One way that Gamma Watermarks may be produced is by selectively adding these radioisotopes to the different inks of a computer inkjet printer.

Dozens of radioisotopes, which are not naturally present in the environment to any significant extent, are suitable for composing a Gamma Watermark. Because each radioisotope emits gamma rays of a different wavelength, combining different radioisotopes in different ratios produces a gamma-ray signature equivalent to an electronic bar code.

As a result of the exquisite sensitivity and energy resolution of modern commercial gamma-ray detectors, which can record a single nuclear decay with high efficiency and precision, the amount of activity required to continuously express a unique digital signature may be as small as a tenth of a nanocurie (billionth of a curie). Correspondingly, the total mass of the watermark may be well under 1 microgram (millionth of a gram).

In addition to the signature, the watermark contains a built-in "clock" that provides a date stamp of its creation. This clock is initially set to a 1:1 ratio of the intensities of two radioisotopes with different half-lives. At any later time, the observed ratio of these two isotope intensities indicates how much time has elapsed since the watermark's creation. The team anticipates that the usual life span of a Gamma Watermark will be a few decades. However, a mixture of radioisotopes could be selected that would last for centuries.

A typical Gamma Watermark measures about 0.01 centimeter in diameter, smaller than the period at the end of this sentence. The watermark can be applied directly to a piece of paper (a stock certificate, for example) or to a practically microscopic solid bead or token for placing on or within virtually any object.

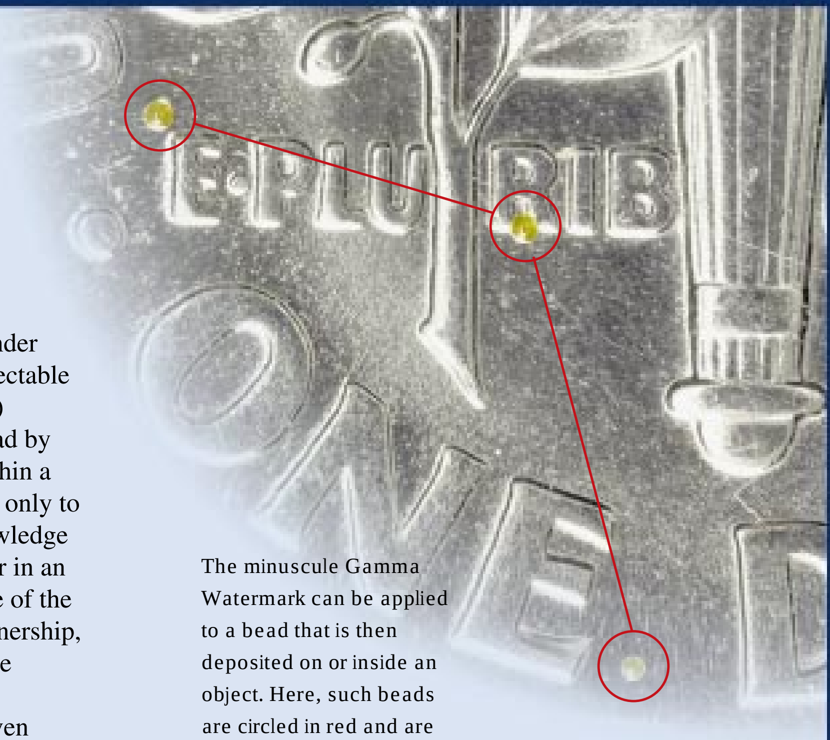
Watermark Can Be Buried

For added security in objects such as museum pieces, the watermark can be placed inside a tiny hole drilled into a piece and then sealed, rendering it virtually invisible, even under close examination. (The gamma rays would still be detectable from buried locations up to a few centimeters in depth.)

The watermark may be detected and its signature read by placing a sensitive gamma-ray detector precisely to within a few millimeters over its location, which may be known only to the object's owner. Indeed, the legitimate owner's knowledge of a Gamma Watermark's secret physical location on or in an object permits its speedy recovery if stolen. Knowledge of the watermark's location also provides confirmation of ownership, which does not depend on the owner's knowledge of the watermark's content.

Rapid detection of the Gamma Watermark occurs even though its total radioactivity is one ten-thousandth of the naturally occurring radioactivity in a human body or a household smoke detector, or a quarter of that of a single banana. Although the watermark's overall intensity is very low, its spectral brightness at certain narrowly defined gamma-ray wavelengths is high and is easily detected.

The extremely low level of gamma-ray emissions, hidden in the ubiquitous natural background radiation, assures complete safety for personnel and helps to further conceal the watermark. Co-inventor Lowell Wood compares detecting the watermark's emissions of less-than-background intensity to someone locating a rare orchid growing deep within a vast rain forest. Without knowing the exact location of an object, someone sweeping for it with a detector might require days to locate its watermark. What's more, the location cannot be discovered through typical examination means such as x rays or sound waves.



The minuscule Gamma Watermark can be applied to a bead that is then deposited on or inside an object. Here, such beads are circled in red and are shown on a dime for scale.

New Weapon for Museums

One of the technology's first uses may be to provide an unprecedented level of theft and counterfeiting protection to museums and collections, both public and private. The U.S. Bureau of Land Management (BLM) is interested in the system as a way of protecting fossils and other artifacts located on public lands. A tagging system based on the Gamma Watermark would aid the BLM and law enforcement agents in recovering fossils illegally obtained from public lands, as well as provide evidence for subsequent prosecution. The system would also allow paleontologists and archaeologists to tag specimens while still in the field. Companies that produce computer software are also interested in the technology as a means of foiling rampant counterfeiters and of permanently branding their products by providing counterfeit-resistant (and hidden) certificates of authenticity.

Although the product price will be determined by companies licensed to use the novel technology, the mass production unit cost of some forms of the Gamma Watermark is estimated to be a small fraction of one dollar. The extraordinarily low price is due to the extremely small quantity of radioisotope needed for each watermark. A small vial of radioisotope, for example, might be sufficient to generate 10 million watermarks. (The cost of reading a Gamma Watermark, of course, is expected to entail much higher costs because of the detection equipment and trained personnel required.)

Team members envision that the technology will gradually infiltrate households. In a few years, someone might purchase a Gamma Watermark kit at an office supply store and use it to uniquely identify a valuable personal possession. From museums to stores to living rooms, the new technology is sure to make an indelible mark on countless items—and help people in all walks of life protect their property.

—Arnie Heller

Key Words: DNA fingerprinting, digital watermark, gamma rays, Gamma Watermark.

For further information contact Muriel Y. Ishikawa (925) 423-4178 (ishikawa1@llnl.gov).